

Review of a Compilation Process: A Map Package based on 15 individual Geological Maps of Ceres

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1. Introduction

One aim of the NASA Dawn mission was to generate global geologic maps of the asteroid Vesta and the dwarf planet Ceres. The geological mapping campaign of Vesta was completed and results have been published in e.g. [1]. Recently also geologic mapping of Ceres has been completed. The tiling used in this mapping project is based on recommendations by [2], and is divided into two parts (for Ceres described in [3,4]): four overview quadrangles (Survey Orbit, 415 m/pixel) and 15 more detailed quadrangles (High Altitude Mapping HAMO, 140 m/pixel). The atlases are available to the public through the Dawn webpage (dawnngis.dlr.de/atlas) and the NASA Planetary Data System (PDS) (pdssbn.astro.umd.edu). The first global geologic map at a scale of 1:2.5 M is based on survey and HAMO images [5]. A more detailed view could be expected within the 15 quadrangles (HAMO tiles, [4]) which were completed by the Low Altitude Mapping (LAMO) data (over 31,300 clear filter images during 11 cycles, 35 m/pixel). Based on these data a global mosaic was created that serves as basis for a high-resolution LAMO atlas that consists of 62 tiles mapped at a scale of 1:250K [6, availability see links above] and was also used as basemap for the mapping project.

For this interpretative mapping one responsible mapper was assigned for each quadrangle. Thus, 15 individual quadrangle maps were conducted at a scale of 1:100K-125K, and published at a scale of 1:1M in the special volume on “The geological mapping of Ceres” [7]. Once the individual tile mapping has been finished, datasets are expected to be “combinable” within ESRI’s ArcGIS platform. Therefore, the mapping process was supported by a mapping template which was developed within the ArcGIS environment and enables a geometrically and visually homogeneous map project. Templates like this are very established in multi-user projects (e.g. within the Geological Mapping Program conducted and guided by the USGS Astrogeology Science Center, ASC) and improves the result of mapping process through pre-defined symbols, object attributes, geometric properties and map sheet elements.

The template presented here contains different layers for different object/geometry types including predefined attribute values and cartographic symbol specifications. The symbols follow guides set up in [8] as far as possible, and colors for geological units were defined according to individual needs and requests within the mapping team. Previous statuses of the mapping compilation process are described in [9, 10].

2. Final map package

The entire mapping project will be available to the community via the PDS annex. All mapping data is saved in an ArcGIS File Geodatabase (fgdb): this contains two *feature data* (fd) sets: the map sheet layer with boundary data and graticule, and mapping layers divided into contacts, units, linear, point, and surface features. All layers are organized as so called *feature classes* (fc). The needed meta information is also defined within the ArcGIS environment. Furthermore, additional data are included:

- *layer files* contain the cartographic visualization stored for every individual thematic layer (*.lyr). Also needed if *.shp are being used instead of fc to receive comparable cartographic visualization.
- *shapes* (*.shp) were extracted from the fgdb for using in other GIS environments.
- *projection* describes the four primary projections for the global data set with a minimum of distortion.
- *project files* are created as *.mxd which shows the whole mapping project within a proprietary map document. *.mpk, *.lpk stores the map project within a compressed map document (proprietary).
- *image files* as *.png show 1. the cartographic legend of the global map, and 2. the global geologic dataset conducted by the merged quadrangle maps is visualized as separate map sheet (in plate carree and stereographic projection, as *.pdf).

3. Critical Review

The current template has served as a necessary basis for mappers to generate their individual – but still comparable – maps, and thus gives the possibility to merge the 15 quads in the future to one global map. The

final status and general information of the mapping project are summarized in [11].

Because the creation of the mapping template was an iterative process, there are still some topics (focus on GIS and cartographic visualization) to discuss on the way to a homogeneous and comparable map layout. These are:

1) *Boundary regions*: Within the review process the mappers should engage to discuss with all neighbours to allow for a clean and consistent description of Ceres.

2) *Map scale and minimum object dimension*: Mapping scale and minimum dimension of planetary objects have to be fixed during the mapping process and double-checked during the review process. Otherwise the impression may arise that some regions show more features than others, where the differences are only a result of the different mapping techniques and lack of mapping constraints.

3) *Boundaries of the quad maps as supplemental material*: The map boundaries defined by the HAMO atlas schema should be consistent for the supplemental material map sheets, independently of whether or not important objects are fully included. Otherwise it would reject the character of the schema which is established for giving a first fully covered and consistent description of the geologic/ geomorphologic of Ceres.

4) *Additional units and colors*: The color scheme was generated by defining one color for each of the units expected by the mappers. These colors should be distinguishable on the map sheet but should still allow a visual affiliation or distinction of the units. Thus, it has to decide very carefully if additional colors for individual and regional phenomena should be used. The global color scheme will be updated if all geological units are clearly and consistently interpreted.

5) *Additional information on the map sheet*: to support the general understanding of the map content it will be useful to provide additional information (like DTM sources, quad schema, or CoMU) on the map sheet. If so, this information should be included uniformly and consistently for all map sheets.

6) *Global relevant feature catalogue*: to describe the different units and features generically and visually it would be useful to combine an updated version of the already existing feature catalog and the generated map legend (applicable to all map quads). This will provide a first global overview of the objects and units identified on Ceres and could be used for a final discussion on individual interpretations and serves as base for a more detailed investigation in the future.

7) *Transferable template*: Beside the proprietary usage within ArcGIS the GIS-based template was also used in the open source software *QGIS* [12]. The template for the final graphical work was transferred into an open format *.svg, so it could be used in a wide range of graphic software tools. Furthermore, the fgdb

schema should be made transferable to open-source database systems (e.g., *PostgreSQL*).

Finally, it should be noted that the merged project still contains some excess objects in overlap areas along the boundary between the quadrangles. This is primarily due to different scientific interpretations of mappers. In order to homogenize this, and to serve a clear topology, follow-up discussions among mappers are required. A detailed description of all those interpretations is published in the papers listed in [7].

4. Conclusion

The compiled map package represents the first global map showing the geology of Ceres on LAMO resolution data at a mapping scale of 1:100-125K within an GIS-based map package, and is published digitally at a scale of 1:2.5M in A0 (as combination of 15 1:1M quadrangle maps [7]). It serves as an accessible basis for upcoming investigations, and is available via the PDS annex with all relevant information. The template developed specifically for Ceres mapping serves as a basis to enable consistent and homogeneous compilation of a global map from 15 individual quadrangle maps. However, while a map template provides the technical framework and allows for consistency, human interaction, iteration and a certain degree of flexibility, a homogenization of the global interpretation is still indispensable in order to arrive at common approach and understanding of mapping boundaries. Thus, only through a final scientific review of the global map dataset and subsequent adjustment of remaining cartographic issues would allow the creating of the homogenous and unified global map product.

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